

In re Patent Application of:

**JIANG ET AL**

Serial No. **10/779,894**

Filed: **FEBRUARY 17, 2004**

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**IN THE CLAIMS**

1. (currently amended) A vertical cavity surface emitting laser comprising:

a lower distributed Bragg reflector;

an active region positioned on the lower distributed Bragg reflector;

an upper distributed Bragg reflector positioned on the active region;

a cylindrical volume removed from the upper distributed Bragg reflector defining a mesa with a substantially vertical side wall concentrically surrounded by the cylindrical volume, an isolation trench formed in a lower surface of the cylindrical volume concentric with the mesa;

an implant region including a portion of the side wall of the mesa and a portion of the upper distributed Bragg reflector below the lower surface of the cylindrical volume;

a planarizing material filling the cylindrical volume;  
and

n and p electrical contacts coupled to opposite sides of the active region for supplying operating current thereto;

wherein the lower surface of the cylindrical volume is formed so that more mirror pairs of the upper distributed Bragg reflector remain adjacent the mesa and less mirror pairs remain as the lateral distance from the mesa increases.

2. (original) A vertical cavity surface emitting laser as claimed in claim 1 wherein the lower surface of the cylindrical volume forms an angle greater than ninety degrees with the side wall of the mesa.

3. (cancelled)

4. (currently amended) A vertical cavity surface emitting laser as claimed in claim 1, 3 wherein the implant region in the lower surface of the cylindrical volume extends at least into the active region adjacent the isolation trench.

5. (original) A vertical cavity surface emitting laser as claimed in claim 1 wherein the planarizing material filling the cylindrical volume includes a low- $k$  dielectric material.

6. (original) A vertical cavity surface emitting laser as claimed in claim 1 wherein the implant region includes at least some of the cylindrical volume surface.

In re Patent Application of:

**JIANG ET AL**

Serial No. 10/779,894

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7. (original) A vertical cavity surface emitting laser as claimed in claim 1 wherein the implant region includes proton implants.

8. (original) A vertical cavity surface emitting laser comprising:

a lower distributed Bragg reflector including a plurality of pairs of mirror elements;

an active region positioned on the lower distributed Bragg reflector;

an upper distributed Bragg reflector including a plurality of pairs of mirror elements positioned on the active region;

a cylindrical volume removed from the upper distributed Bragg reflector defining a mesa with a substantially vertical side wall concentrically surrounded by the cylindrical volume, an isolation trench formed in a lower surface of the cylindrical volume concentric with the mesa, the lower surface of the cylindrical volume being formed so that more mirror pairs of the upper distributed Bragg reflector remain adjacent the mesa and less mirror pairs remain as the lateral distance from the mesa increases whereby the lower surface of the cylindrical volume forms an angle greater than ninety degrees with the side wall of the mesa;

an implant region adjacent a surface of the cylindrical volume including the side wall of the mesa and the upper distributed Bragg reflector defining the lower surface of the cylindrical volume;

In re Patent Application of:

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a planarizing material filling the cylindrical volume; and

n and p electrical contacts coupled to opposite sides of the active region for supplying operating current thereto.

9. (currently amended) A method of fabricating a high frequency vertical cavity surface emitting laser comprising the steps of:

a) providing a lower distributed Bragg reflector on a substrate, an active region on the lower distributed Bragg reflector, and an upper distributed Bragg reflector on the active region;

b) etching a cylindrical volume from the upper distributed Bragg reflector to define a mesa with a substantially vertical side wall, the cylindrical volume extending into the upper distributed Bragg reflector to a lower surface adjacent the active region;

c) etching an isolation trench in the lower surface of the cylindrical volume concentric with the mesa and extending through the active region;

d) implanting a portion of the side wall of the mesa and the lower surface of the cylindrical volume; and

e) planarizing the upper distributed Bragg reflector and coupling n and p electrical contacts to opposite sides of the active region for supplying operating current thereto;

In re Patent Application of:

**JIANG ET AL**

Serial No. **10/779,894**

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wherein step b) includes etching the cylindrical volume so that the lower surface of the cylindrical volume forms an angle greater than ninety degrees with the side wall of the mesa, and etching the cylindrical volume so that more mirror pairs of the upper distributed Bragg reflector remain adjacent the mesa and less mirror pairs remain as the lateral distance from the mesa increases.

10. (cancelled)

11. (cancelled)

12. (currently amended) The method of claim 9, ~~11~~ wherein ~~the step d) of implanting~~ includes proton implanting the side wall of the mesa and the lower surface of the cylindrical volume.

13. (currently amended) The method of claim 12, wherein ~~the step d) of proton implanting the lower surface of the cylindrical volume~~ includes implanting the lower surface of the cylindrical volume so that the implant extends at least into the active region adjacent the isolation trench.

14. (currently amended) The method of claim 9, wherein ~~the step a) of providing~~ includes epitaxially growing the lower distributed Bragg reflector on the substrate, epitaxially growing the active region on the lower distributed Bragg reflector, and epitaxially growing the upper distributed Bragg reflector on the active region.

15. (currently amended) The method of claim 9, wherein ~~the step e) of planarizing~~ includes filling the cylindrical volume

In re Patent Application of:

**JIANG ET AL**

Serial No. 10/779,894

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with one of benzocyclobutene (BCB) dielectric and a polyimide material.

16. (original) A method of fabricating a high frequency vertical cavity surface emitting laser comprising the steps of:

epitaxially growing a lower distributed Bragg reflector on a substrate, epitaxially growing an active region on the lower distributed Bragg reflector, and epitaxially growing an upper distributed Bragg reflector on the active region;

etching a cylindrical volume from the upper distributed Bragg reflector to define a mesa with substantially vertical side wall, the upper distributed Bragg reflector being etched so that a lower surface of the cylindrical volume forms an angle greater than ninety degrees with the side wall of the mesa, and further etching the cylindrical volume so that more mirror pairs of the upper distributed Bragg reflector remain adjacent the mesa and less mirror pairs remain as the lateral distance from the mesa increases;

etching an isolation trench in the lower surface of the cylindrical volume concentric with the mesa and extending through the active region;

proton implanting a portion of the side wall of the mesa and the lower surface of the cylindrical volume; and

planarizing the upper distributed Bragg reflector and coupling n and p electrical contacts to opposite sides of the active region for supplying operating current thereto.

In re Patent Application of:

**JIANG ET AL**

Serial No. **10/779,894**

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17. (original) The method of claim 16 wherein the step of proton implanting the lower surface of the cylindrical volume includes implanting the lower surface of the cylindrical volume so that the implant extends at least into the active region adjacent the isolation trench.

18. (original) The method of claim 16 wherein the step of planarizing includes filling the cylindrical volume with one of BCB dielectric and a polyamide.

19. (new) A vertical cavity surface emitting laser comprising:

a lower distributed Bragg reflector including a plurality of pairs of mirror elements;

an active region positioned on the lower distributed Bragg reflector;

an upper distributed Bragg reflector including a plurality of pairs of mirror elements positioned on the active region;

a cylindrical volume removed from the upper distributed Bragg reflector defining a mesa with a substantially vertical side wall concentrically surrounded by the cylindrical volume, the lower surface of the cylindrical volume being formed so that more mirror pairs of the upper distributed Bragg reflector remain adjacent the mesa and less mirror pairs remain as the lateral distance from the mesa increases whereby the lower surface of the cylindrical volume forms an angle greater than ninety degrees with the side wall of the mesa;

In re Patent Application of:

**JIANG ET AL**

Serial No. 10/779,894

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---

an implant region adjacent a surface of the cylindrical volume including the side wall of the mesa and the upper distributed Bragg reflector defining the lower surface of the cylindrical volume;

a planarizing material filling the cylindrical volume; and

n and p electrical contacts coupled to opposite sides of the active region for supplying operating current thereto.

20. (new) A vertical cavity surface emitting laser as claimed in claim 19, wherein the implant region in the lower surface of the cylindrical volume extends at least into the active region.

21. (new) A vertical cavity surface emitting laser as claimed in claim 19, wherein implant region in the lower surface of the cylindrical volume extends into the a lower distributed Bragg reflector.

22. (new) A vertical cavity surface emitting laser as claimed in claim 1, wherein implant region in the lower surface of the cylindrical volume extends into the a lower distributed Bragg reflector.

23. (new) The method of claim 12, wherein step d) includes implanting the lower surface of the cylindrical volume so that the implant extends into the lower distributed Bragg reflector adjacent the isolation trench.